REMARKS

Claims 7 and 41-64 are pending in this application. Applicants thank the Examiner for the indication that claim 47 includes patentable subject matter. Applicants respectfully request entry of the amendments to claim 7 and reconsideration thereof, and entry and consideration of claims 41-64.

Rejections of the Claims

Claims 58-64 have been rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the enablement requirement. Claims 7 and 41-45 have been rejected under 35 U.S.C. §112, second paragraph, as being indefinite. Claims 46, 48, 50, 53, 54, 56, and 57 have been rejected under 35 U.S.C. §102(e) as being anticipated over Dai et al. (US 6,528,020) with evidence by Dijksma et al. (Anal. Chem., 2001, 73, pp. 901-907). Claims 7, 41-43, and 45 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Cui et al. (Science, 293, August 2001, 1289-1292) in view of Krstic et al. (Electronic Properties of Novel Materials-Molecular Nanostructures, 2000, pp. 367-370). Claims 7, 43 and 44 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Dai et al. in view of Krstic et al. Claims 41, 42, and 45 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Dai et al. and Krstic et al. in further view of Cui et al. with evidence of Heo et al. (App. Phys. Let., 2002, 18, pp. 3046-3048). Claims 51, 52, and 55 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Dai et al. in view of Cui et al. with evidence of Heo et al. Claim 44 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Cui et al. and Krstic et al. in further view of Dai et al. Claims 46, 48, and 49 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Cui et al. in view of Krstic et al. with evidence by Dijksma et al. Claims 50-57 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Cui et al. in view of Dai et al. Claims 58-64 have been rejected under 35 U.S.C. §102(b) or §102(e) as anticipated by, or in the alternative, under §103(a) being unpatentable over either Cui et al. or Dai et al. with or without the further teaching of Krstic et al.

Rejections under 35 U.S.C. §112, First Paragraph

Claims 58-64 have been rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the enablement requirement. With respect to claim 58, the Examiner has objected to the limitation of "measuring a change in a work function of one of the two electrodes" and argues that "applicant does not appear to ever relate back this resistance back to a changing work function" and "absent any explicit step of measuring a work function or relating the measured resistance back to a work function, this new limitation is not enabled" (Office Action page 2). Applicants respectfully disagree that measuring a change in the work function is not enabled.

Paragraph [0032] clearly sets forth that the resistance of the nanotube device comprises channel and contact resistances, and that contact resistance depends on the work function of the metal of the electrode. Paragraph [0032] then notes that the examples that follow the paragraph show how the work function change of at least one of the electrodes can be used for sensing molecules in fluids. Thereafter, Example 1 makes reference to Figure 4A which shows the change in current as a function of time with alternating exposure to 2% H_2 in air for a sensor of the invention having Pd electrodes. "As a control, a device with Ti electrodes connected to nanotubes did not show a response upon exposure to 2% H_2" (page 11 paragraph [0035]). Accordingly, in paragraph [0032] the specification says that the examples show how the work function change can be used for sensing, and with respect to Example 1 a plot of current vs. a changing concentration of H_2 is provided. Accordingly, Example 1 relates a measured current change back to a work function change. As is well known, voltage, current, and resistance are related by V=IR. Thus, measuring a current change is effectively the same as measuring a resistance change. Therefore, the measured current change with exposure to H_2 relates to a change of the contact resistance and to the altered work function of the Pd.

It is clear that neither the work function of the nanotube, nor the channel resistance of the nanotube, was affected by the exposure to H_2 because the device with Ti electrodes did not show a response. Applicants do not see any other explanation for the results of Example 1 other than exposure to H_2 caused a change in Pd work function that altered the contact resistance, and this change in contact resistance lead to a measurable

change in current. As no other phenomenological basis for the change in current is present, measuring the change in current enables the limitation of measuring a change in the work function.

Applicants note for the record that a change in the work function of the electrode can be measured in a number of ways that were not discussed in the specification but that would be well within the skill of those of ordinary skill in the art of such sensors. For example, photo-emission spectroscopy (PES) or a Kelvin probe can be used. The availability of these well known techniques for measuring changes in work function would have been enough to allow one of ordinary skill in the art at the time of the invention to practice the invention of claim 58 without undue experimentation.

Regarding claim 63, the Examiner has objected to the limitation of "measuring a Schottky barrier defined between the nanoelement and the one of the two electrodes" (Office Action page 3). Applicants again respectfully disagree. As noted above, the work function can be measured in a number of ways. One way is to measure contact resistance which "is defined by the Schottky barrier" (page 9 paragraph [0032]). In Example 1, discussed above, the contact resistance is the only phenomenological basis for the observed change. Applicants additionally note that if one were to expect an interaction between the molecule to be sensed and the nanoelement and that the interaction would influence the channel resistance, the nanoelement can be coated with a protective layer (page 15 paragraph [0041]) to limit the measurement to only the Schottky barrier.

For the reasons provided above, claims 58 and 63 are enabled within the meaning of 35 U.S.C. §112, first paragraph. Accordingly, Applicants request that the Examiner withdraw the rejections of claim 58, and claims 59-64 depending therefrom, under 35 U.S.C. §112, first paragraph.

<u>Rejections under 35 U.S.C. §112, Second Paragraph</u>

Claims 7 and 41-45 have been rejected under 35 U.S.C. §112, second paragraph, as being indefinite. Specifically, claim 7 has been rejected because "a nanoelement" is later referred to as "the nanotube." Claim 7 has been amended to recite "the nanoelement" in place of "the nanotube." Accordingly, claim 7 is definite within the

meaning of 35 U.S.C. §112, second paragraph. Applicants therefore request that the Examiner withdraw the rejections of claim 7, and claims 41-45 depending therefrom, under 35 U.S.C. §112, second paragraph.

Rejections of Claims 7 and 41-45

Independent claim 7, and claims 41-45 depending therefrom, have been rejected under 35 U.S.C. §103(a) as being unpatentable over either Cui et al. or Dai et al. in view of Krstic et al., or over Dai et al. and Krstic et al. in further view of Cui et al. with evidence of Heo et al. Independent claim 7, as further amended, recites a surface coating that includes Pd. The Examiner states, with respect to Krstic et al., that "any electrode constructed of Pd would inherently have a surface layer comprising Pd." (Office Action page 5, paragraph 15) Applicants have amended claim 7 to replace "surface layer" with "surface coating." A coating is defined as "any substance spread over for cover or protection; as, a *coating* of enamel" (Webster's New Twentieth Century Dictionary, 2nd Edition, 1983). Clearly, a coating is distinct from that which is coated. Accordingly, any electrode constructed of Pd would not inherently have a surface coating comprising Pd. For example, the Pd electrode could be uncoated. In such an example, even though the surface may include Pd, it would be incorrect to say that the electrode included a surface coating of Pd.

The Examiner further argues that even if claim 7 were to require "a unique coating of palladium distinct from the remainder of the electrode" that Krstic et al. provides the motivation for one of ordinary skill in the art to provide such a coating. (Office Action pages 11-12, paragraph 36) The Examiner refers back to paragraph 17 of the prior Office Action for the argument that "the materials of Krstic need only be present as a coating on the final electrode in order to still provide the set forth contact resistance." Applicants respectfully disagree with this conclusion.

Krstic et al. describes electrodes defined on top of carbon nanotubes in order to reduce the contact resistance between metal and nanotube (Abstract). The resistance being measured is clearly at the interface of the metal and the nanotube. As one example, aluminum was deposited as the electrodes and "no measurable current ($I > 0.5$ pA) could be observed for up to a few volts" (p. 369). "The results obtained with Al demonstrate

that metals can have a significant influence on the contact properties" (p. 370). Also, adhesion problems observed with other metals "may lead to a mechanical increase of the SWNT/metal distance" (p. 370). Clearly, Krstic et al. is concerned with the dependency of the contact resistance on the interface between the electrode and the nanotube and does not teach or suggest that the same contact resistance would be observed if the metal of interest were merely present as a surface coating on an electrode with an otherwise different composition. One of ordinary skill in the art would not conclude, for example, that aluminum need only be present as a coating on the surface of the gold electrodes of Krstic et al. to provide the set forth contact resistance observed for aluminum, namely, a resistance so high that no measurable current could be observed for up to a few volts. Likewise, one of ordinary skill in the art would not conclude that an aluminum electrode with a gold coating would provide the I/V relationships shown in FIG. 4. Accordingly, Krstic et al. does not provide the motivation for one of ordinary skill in the art to provide a unique coating distinct from the remainder of the electrode.

Since Krstic et al. does not provide the motivation to provide a surface coating including palladium over an electrode, claim 7 is patentable over Cui et al. in view of Krstic et al. and Dai et al. in view of Krstic et al. Applicants therefore request that the Examiner withdraw the rejections of claim 7, and claims 41-45 depending therefrom, under 35 U.S.C. §103(a).

Rejections of Claims 46, 48, and 49

Claims 46 and 48 have been rejected under 35 U.S.C. §102(e) as being anticipated over Dai et al. with evidence by Dijksma et al. and claims 46, 48, and 49 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Cui et al. in view of Krstic et al. with evidence by Dijksma et al. Independent claim 46 recites one electrode comprising a surface coating including a molecule with an affinity for a bio-molecule. The Examiner cites to col. 2 lines 52-53 of Dai et al. for the teaching that Dai et al. teaches an electrode having a gold layer. However, the cited portion of Dai et al. merely teaches that the electrode may "typically comprise an alloy of nickel-gold, or titanium-gold" (col. 2 lines 52-53). Clearly, this teaching goes to the composition of the electrodes themselves, and does not teach or suggest surface coatings on the electrodes.

Dai et al. does teach a coating of PMMA with reference to the results shown in FIG. 6. In this example the responses of two devices are compared, an as-grown nanotube film device and "a PMMA-coated nanotube film device" (col. 3 lines18-19). It is apparent that the entire device, including the electrodes and nanotubes, is coated with PMMA. Although the PMMA is coated on the electrodes as well as the nanotubes, Dai et al. indicates only that the PMMA improves sensitivity to NO_2 which is a simple inorganic oxide and not a bio-molecule. Clearly, Dai et al. does not teach or suggest an embodiment in which the electrode is coated with a molecule with an affinity for a bio-molecule. Applicants therefore request that the Examiner withdraw the rejections of claim 46, and claim 48 depending therefrom, under 35 U.S.C. §102(e).

For essentially the reasons provided above with respect to claim 7, Applicants assert that claim 46 is also patentable over Cui et al. in view of Krstic et al. Applicants therefore request that the Examiner withdraw the rejections of claim 46, and claims 48 and 49 depending therefrom, under 35 U.S.C. §103(a).

Rejections of Claims 50 and 51-57

Claims 50, 53, 54, 56, and 57 have been rejected under 35 U.S.C. §102(e) as being anticipated over Dai et al. with evidence by Dijksma et al. Claims 51, 52, and 55 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Dai et al. in view of Cui et al. with evidence of Heo et al. Claims 50-57 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Cui et al. in view of Dai et al.

Independent claim 50, as amended, recites a sensor comprising a nanoelement, a pair of electrodes, and a protective layer over the nanoelement, but not over at least one of the electrodes. With respect to the rejection over Dai et al. under 35 U.S.C. §102(e), as discussed above, Dai et al. does not teach or suggest a protective layer over the nanotube but not over the electrodes. With respect to the rejection over Cui et al. in view of Dai et al. under 35 U.S.C. §103(a), neither Dai et al. nor Cui et al. teach or suggest a protective layer over the nanotube but not over the electrodes. Applicants note that one of ordinary skill in the art would not have been inclined to modify the inventions of either reference such that the nanotubes were coated while the electrodes specifically were not uncoated. Particularly, this would involve a further masking step to prevent coverage of

the electrodes, which introduces further complexity and cost into the fabrication process. And neither reference provides a suggestion of a benefit that would justify such an added step. To the contrary, both references focus on influencing the surfaces of the nanotubes and not the surfaces of the electrodes. For example, in Dai et al. the metal electrodes provide "means for measuring electrical response of the nanotube" (col. 2 lines 17-20). Also, "[t]he nanotube thus produced can be further modified by coating or decorating with one or more sensing agents ... which impart sensititvity to a particular molecular species" (col. 2 lines 32-37). Accordingly, Applicants assert that claim 50 is neither anticipated by Dai et al. under 35 U.S.C. §102(e) nor unpatentable over Cui et al. in view of Dai et al. Applicants therefore request that the Examiner withdraw the rejections of claim 50, and claims 51-57 depending therefrom, under 35 U.S.C. §102(e) and 35 U.S.C. §103(a).

Rejections of Claims 58 and 59-64

Claims 58-64 have been rejected under 35 U.S.C. §102(b) or §102(e) as anticipated by, or in the alternative, under §103(a) being unpatentable over either Cui et al. or Dai et al. with or without the further teaching of Krstic et al. Claim 58 recites a method of sensing a specific molecule comprising measuring a change in a work function of one of the two electrodes in response to the environment. Neither Cui et al. nor Dai et al. teaches or suggests measuring a change in a work function. In Cui et al. sensors for pH, streptavidin, and calcium ions are discussed. In each example the surface of the silicon nanowire is modified to be particularly receptive to the species of interest. The graphs in Figs. 1-4 illustrate the dependence of conductance on the concentration of the three species. As discussed above with respect to the enablement of claim 58, the present disclosure notes that the resistance of such nanotube devices comprises channel and contact resistances. Here, the change being measured is a change in the channel resistance and not a change in the contact resistance. There is no teaching or suggestion in the cited art that the work function of the electrodes change as a function of concentration. Since the work function of the electrodes do not change, Cui et al. does not teach or suggest measuring a change in a work function of one of the two electrodes in response to the environment, as required by claim 58.

Similarly, Dai et al. "provides methods for modifying the nanotubes such that their sensitivity to a wide range of chemical and biological species can be achieved" (Abstract). For essentially the reasons provided above, Dai et al. also measures only changes in the channel resistance of the nanotubes and not changes in the work function of the electrodes. Thus, Dai et al. also does not teach or suggest measuring a change in a work function of one of the two electrodes in response to the environment, as required by claim 58.

Applicants note that substituting the PdAu alloy of Krstic et al. for the unspecified electrode material of Cui et al. or the nickel-gold or titanium-gold electrodes (col. 4 lines 64-65) of Dai et al. would not change the basic functioning of their respective sensors. Thus, even if one were to make the proposed substitution the sensors would still measure changes in the channel resistance of the nanotube or nanowire and not a change in a work function of one of the two electrodes. Applicants therefore request that the Examiner withdraw the rejections of claim 58, and claims 59-64 depending therefrom, under 35 U.S.C. §§102(b) and (e) and 35 U.S.C. §103(a).

CONCLUSION

All pending claims are now allowable and Applicants respectfully request a Notice of Allowance from the Examiner. Should the Examiner have questions, the Applicants' undersigned attorney may be reached at the number provided.

Respectfully submitted,

Gang Gu et al.

Date: March 2, 2005 By: [signature]

Robert Hayden, Reg. No. 42,645
Carr & Ferrell *LLP*
2200 Geng Road
Palo Alto, CA 94303
Phone (650) 812-3465
Fax (650) 812-3444